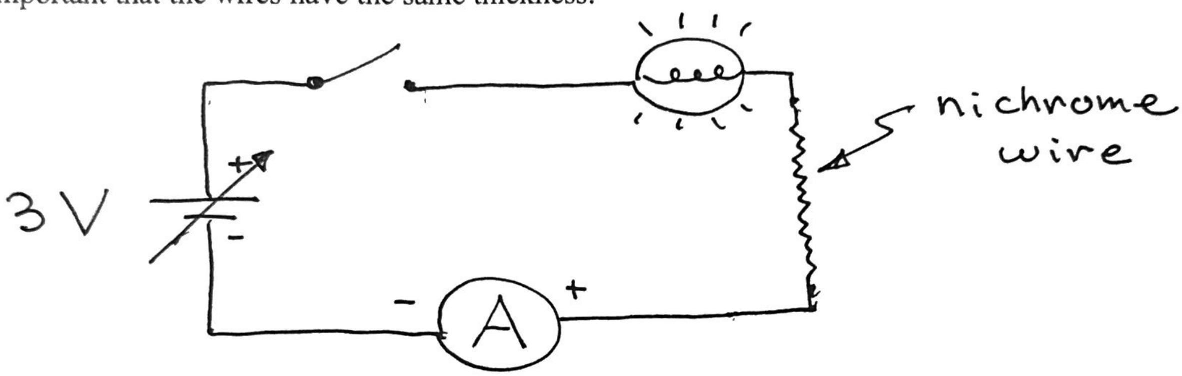
Resistance of a wire

For many circuit elements, including metal wires, the ratio of the potential difference or voltage across the wire to the current through the wire, $\Delta V / I$, is constant for a large range of currents. This ratio is called the resistance of the wire and is a measure of the wire's resistance to the flow of electric current through it. Resistance has units of V/A or ohms (Ω). In this lab you will investigate how a wire's length, cross-sectional area, and material influence its resistance.

<u>Experiment 1: How does resistance depend on length?</u> Build a circuit consisting of the power supply set at about 3 volts, clip leads, a round bulb, a length of thin nichrome wire, and an ammeter. See the diagram below. The bulb serves to limit the current through the circuit. Measure the current through the nichrome wire with your ammeter and then the potential difference a cross the wire with your digital voltmeter. Try to measure current and voltage to three significant figures if possible. Determine the resistance of the nichrome wire. Now repeat the measurements using a thin nichrome wire with about (1) twice the length and then (2) four times the length of the first wire. Note: it is important that the wires have the same thickness.



<u>Question</u>: Based on these measurements, how does resistance vary with length? Explain your reasoning and back it up with numbers! To be quantitative, compare the ratio of resistance values with the ratio of respective lengths.

<u>Experiment 2: How does resistance depend on the thickness of wire?</u> Build a circuit using two nichrome wires with different *thickness* but having the same length. Again, measure the voltage across each wire and the current through each. Measure the diameter of each wire and calculate each wire's cross-sectional area. Use these measurements to determine how resistance varies as the cross-sectional area of the wire changes. Be quantitative: compare the ratio of resistances to the ratio of areas.

<u>Resistivity</u>: The resistivity (ρ) of a material such as nichrome is related to resistance by the following equation: $R = \rho \ell / A$. Resistivity should be a constant value for a given material. Determine the resistivity of each section of nichrome that you have used today. Is the resistivity of nichrome about the same for each of the wires?

Experiment 3: Build a circuit as before, only now using two wires of the same length, one a thin nichrome wire and the other a thin copper wire. Measure the current through each of these wires and the potential difference across each. If you put both wires in series, you can build one circuit for both measurements. Find the length and cross-sectional area of each wire. From your measurements determine the resistivity for both copper and nichrome.

Question: Which has a larger resistivity? How do the different values of resistivity affect the potential difference across the two similar-sized wires?

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Resistance of a wire

$I = \frac{\Delta V}{R}$

$R = \frac{\Delta V}{I}$

Experiment 1

$D = 0.25\,mm$ $I_1 = 275 \times 10^{-3} A$ ⇐ Ammeter
$L = 10.2\,cm$ $\Delta V_1 = 0.432\,V$ ⇐ Voltemeter
$r = 0.175\,mm$ $R_1 = 1.57\,\Omega$

$D_2 = 0.35\,mm$ $I_2 = 260 \times 10^{-3} A$
$L_2 = 20.4\,cm$ $\Delta V_2 = 0.741\,V$
$R_2 = 2.85\,\Omega$

$D_3 = 0.35\,mm$ $I_3 = 211 \times 10^{-3} A$
$L_3 = 40.8\,cm$ $\Delta V_3 = 1.245\,V$
$R_3 = 5.9\,\Omega$

The resistance will increase with an increased wire length.

ie $R_1 = 1.57\,\Omega$ $L_1 = 10.2\,cm$
$R_2 = 2.85\,\Omega$ $L_2 = 20.4\,cm$
$R_3 = 5.9\,\Omega$ $L_3 = 40.8\,cm$
↓ increasing

Increases with length of wire

L : 1 : 2 : 4
R : 1 : 1.8 : 3.7

$R_1 : R_2 : R_3$
1 : 1.8 : 3.7

Experiment 2

$R = \frac{\Delta V}{I}$

T = Thicker
S = Smaller

$\Delta V_T = 0.097\,V$ $I_T = 290 \times 10^{-3} A$ $R_T = 0.334\,\Omega$
$\Delta V_S = 0.399\,V$ $I_S = 290 \times 10^{-3} A$ $R_S = 1.376\,\Omega$
$D_T = 0.67$

R : 1 : 4.12
T : S

$R_T : R_S$
1 : 4.12

$R_T = 0.33\,mm$
$R_S = 0.165\,mm$

A : A_T : A_S

Thick to thin
A : 4 : 1 = Area
R : 1 : 4 = Resistance

$A = \pi r^2$
$A_T = \pi (0.33)^2 = 0.342\,mm^2$
$A_S = \pi (0.165)^2 = 0.086\,mm^2$

$R_T = 0.334\ \Omega$
$R_S = 1.376\ \Omega$

$A_T = 3.421 \times 10^{-7}\ m^2$
$A_S = 8.553 \times 10^{-8}\ m^2$
$l_T = 10 \times 10^{-2}\ m$
$l_S = 10 \times 10^{-2}\ m$

$$\rho_T = \frac{(3.421 \times 10^{-7}\ m^2)(0.334\ \Omega)}{(10 \times 10^{-2}\ m)}$$

$$\rho_T = 1.143 \times 10^{-6}\ \Omega m$$

$$\rho_S = \frac{(8.553 \times 10^{-8}\ m^2)(1.376\ \Omega)}{(10 \times 10^{-2}\ m)}$$

$$\rho_S = 1.177 \times 10^{-6}\ \Omega m$$

$R_1 = 1.57\ \Omega$
$l_1 = 10.2 \times 10^{-2}\ m$
$A = \pi(0.175 \times 10^{-3}\ m)^2$

$$\rho_1 = \frac{\pi(0.175 \times 10^{-3}\ m)^2 (1.57\ \Omega)}{(10.2 \times 10^{-2}\ m)}$$

$$\rho_1 = 1.481 \times 10^{-6}\ \Omega m$$

$R_2 = 2.85\ \Omega$
$l_2 = 20.4 \times 10^{-2}\ m$
$A = (\pi(0.175 \times 10^{-3}\ m)^2$

$$\rho_2 = \frac{\pi(0.175 \times 10^{-3}\ m)^2 (2.85\ \Omega)}{(20.4 \times 10^{-2}\ m)}$$

$$\rho_2 = 1.344 \times 10^{-6}\ \Omega m$$

$R_3 = 5.9\ \Omega$
$l_3 = 40.8 \times 10^{-2}\ m$
$A = (\pi(0.175 \times 10^{-3}\ m)^2)$

$$\rho_3 = \frac{\pi(0.175 \times 10^{-3}\ m)^2 (5.9\ \Omega)}{40.8 \times 10^{-2}\ m}$$

$$\rho_3 = 1.391 \times 10^{-6}\ \Omega m$$

The resistivity is about the same, they are all in the same ball park

Experiment 3

C = copper
N = Nichrome

$l_C = 10 \times 10^{-2}\ m$
$l_N = 10 \times 10^{-2}\ m$

$r_C = 0.165 \times 10^{-3}\ m$
$r_N = 0.165 \times 10^{-3}\ m$

$\Delta V_C = 0.012\ V$
$\Delta V_N = 0.858\ V$
$I_C = 0.5\ A$
$I_N = 0.5\ A$